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SCHOOL SIZE ESTIMATES AND OTHER
RESULTS FROM AERIAL PHOTOGRAPHS TAKEN
DURING THE 11 OCTOBER-24 NOVEMBER
CRUISE OF THE F/V GINA ANNE

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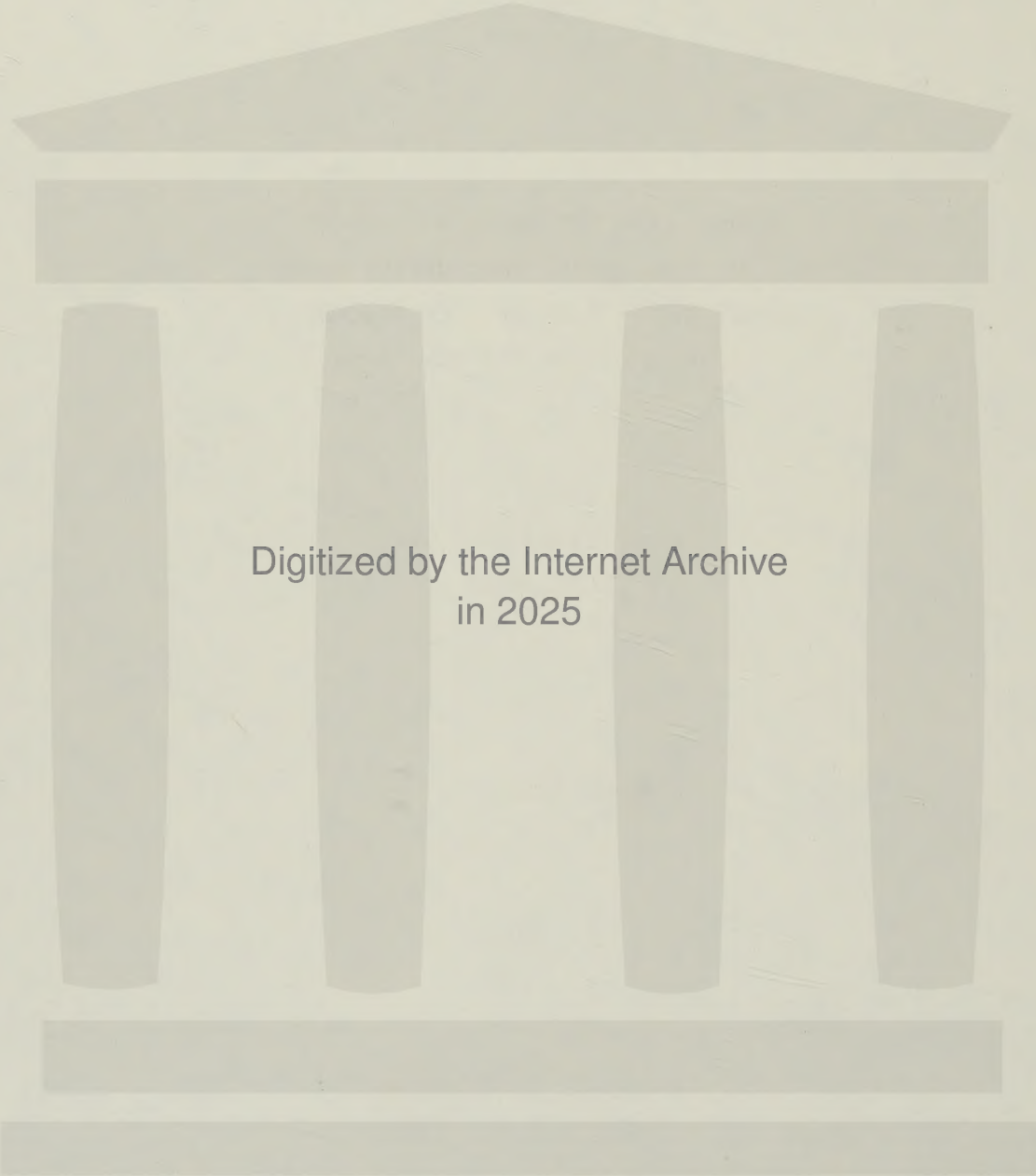
School size estimates and other
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INTRODUCTION

Aerial photography has become a valuable tool for developing school size estimates for pelagic porpoise schools. The technique has been used in the tropical Pacific (Holt and Powers, 1979) and in temperate waters off northern California and the Hawaiian Islands (T. Dohl, pers. comm.).

A major objective of the joint Inter-American Tropical Tuna Commission (IATTC)/National Marine Fisheries Service (NMFS) school size experiment conducted during October and November of 1979 was to determine the accuracy of school size estimates derived from aerial photographs by comparing them with whole school counts. A description of the counting technique and the results of this effort are presented in the IATTC cruise report (Allen, et al., 1980). Here I describe the photographic techniques employed, the equipment used, and the estimates that were generated from data collected during that cruise. I also compare these results with other sets of estimates and makes some suggestions for future uses of aerial photography in porpoise research.

METHODS AND MATERIALS

The F/V *Gina Anne*, a 214 foot tuna purse seiner with approximately 1200 tons of fish carrying capacity, was chartered by the IATTC for the experiment. The vessel carried a Bell 47A helicopter with a Soloy conversion gas turbine engine. A U.S. Navy KA51A aerial reconnaissance camera was mounted to the frame of the helicopter just aft of the passenger bubble and adjacent to the engine. A control box was mounted between the pilot and observer seats which allowed the scientist to vary shutter speed and to fire the camera manually or to have it fired automatically at intervals of from 1 to 10 seconds. Kodak Aerochrome 2448/5" format film was used in this camera.

Additional aerial photography was conducted using a Hasselblad 500EL camera with an 80 mm lens and 120 mm film backs, and with a Canon F-1 with a standard 50 mm lens. Both Kodak Ektachrome 200 and 400 were used in the Hasselblad while only Ektachrome 400 was used in the Canon F-1. The Hasselblad was used along with the 5" camera for whole school photography. Both the Hasselblad and Canon systems were used to photograph porpoise schools in the purse seine net.

Weather conditions permitting (Beaufort 4 and below), the scientist was aboard the helicopter searching for porpoise schools 4-6 hours a day. Search speed was 65-70 miles per hour at an altitude of from 650 to 750 feet. When a school was sighted from the ship or the helicopter, the scientist in the helicopter provided the ship with an approximate estimate of school size (generally small, medium, or large), species composition, and the amount of tuna with the school. If a set appeared likely and sea state, time of day, and school configuration were favorable, whole school photographs were attempted. Passes for 5" photography were generally between 900-1100 feet while those for the Hasselblad were often between 700-900 feet. The 5" camera was set at an f-stop of 2.8 and shutter speed of 1/400th of a second. Settings for the Hasselblad varied with time of day and amount of overcast.

Upon completing the photographic runs, a pass was occasionally made for a visual school size estimate. Unfortunately, it was necessary to return to the ship as soon as possible to increase the probability of the vessel catching all or most of the school. This frequently limited the effort to just the photographic passes.

The helicopter returned to the ship and the scientist was replaced by an experienced crew member who remained in the helicopter until the bow and stern ortzas were onboard. The scientist returned to the helicopter to take additional photographs after the rings were up. While the net was being hauled aboard, repeated photographic passes were made at between 350 and 800 feet to compare image clarity and water penetration in photographs taken with a Wratten 3 filter or a polarizing filter with those taken without filters.

Upon returning to San Diego, the Hasselblad and Canon films were processed by Kodak. The 5" film was processed at normal temperatures by Rapid Color Laboratories in Glendale, California. All of the transparencies were reviewed on a light table and those photographs or sets of photographs that appeared to be of good quality and to include the entire school were separated for further analyses. The Hasselblad slides were projected against a large easel and individual animals were marked on the paper. The 5" film was taken to the NASA facility in Bay St. Louis, Mississippi, where it was enlarged and analyzed on Variscan Mark II projectors. A clear sheet of plastic was placed over the viewing screen of the Variscan machines and the animals were marked as described above.

A team of 5 scientists were selected to review the photographs. Dr. Barham, LCDR Perryman, and LT Jackson of the NMFS had been involved in processing photographs from previous aerial surveys. Mr. Laake and Mr. Scott of the IATTC had no previous experience at making estimates from aerial photographs and they were given a brief indoctrination in the procedure before processing their first school. The estimates were made independently and were based upon the number of animals marked, the quality of the photograph, the opinion of the reviewing scientist concerning the visibility of all school boundaries, the swimming behavior of the animals, and any notes that were taken at the time the school was photographed. The scientists were not informed of the field estimates for these schools until the experiment was completed.

Some of the 5" transparencies were of adequate quality for measurement of animal lengths to be made. On our first attempt at this procedure a direct reading compass was used to measure lengths on the Variscan screen. After a series of measurements, a consensus was reached on the average adult length and all animals at least 2 mm smaller than that average size were measured and recorded. A 7X hand lens with a millimeter scale was used to measure all the animals of a second school.

RESULTS

School size estimates were made from photographs of 11 schools (Table 1). For schools that were evaluated in both 2 1/4" and 5" format, the best set of estimates from each format were included for comparison. The two right hand columns of the table list the best estimates of school size based on counts at backdown plus an estimate of evasion, and the mean estimate of the percent of the school captured. For all suitable schools the correlation coefficient between photographic estimates and estimates from backdown counts, is 0.89. Estimates made by the scientist in the helicopter were also positively correlated with the photographic estimates (0.84). A linear regression forced through the origin for these two sets of estimates was significant at the 0.05 level, (Figure 1). The slope was very close to unity ($\beta = 1.0023$). Estimates of school size from photographs and chase estimates made by shipboard scientists and crew members and the crew member who stayed in the helicopter during the chase and set were positively correlated (Table 2).

Since it may be helpful to compare the estimates from this study with those

from photographs of the 1979 aerial survey, 2 slides that were taken during the 1979 aerial survey were included with the helicopter study slides. With the exception of the author, none of the scientists making the counts knew that these slides were from another source. Table 3 shows the average estimates and the range of estimates for these slides. Counts made from these slides in 1979 are also included in the table for comparison.

Dolphin length measurements from aerial photographs of schools 72 and 127 are presented in Table 4. Measurements (m) can be converted to actual animal lengths (ℓ) as:

$$\ell = m \frac{\text{altitude}}{(\text{lense focal length})(\text{image magnification})}$$

$$\text{for school 72 } \ell = (m) \frac{1100 \text{ feet}}{(0.5 \text{ feet}) (31.8)} = m(69.18)$$

$$\text{for school 127 } \ell = (m) \frac{900 \text{ feet}}{(0.5 \text{ feet}) (12)} = m(150)$$

The average adult length for school 72 was estimated to be 25 mm in measurement units or 1729.5 mm in actual length. A frequency distribution of length measurements for school 127 was constructed (Figure 2) and dolphins longer than 10.5 mm as measured were interpreted as adults. The average length for these adult animals was 1788.0 mm in actual length. Repeated measurements of dolphins in school 127 by two scientists indicated that the hand lense measuring system was accurate to approximately 1.0 mm.

The results of the filter comparison tests were inconclusive because it was impossible to fire cameras with and without filters at the same time. The results imply, however, that image quality can be significantly improved by the use of a pale yellow filter to absorb color noise at wave lengths below 400 nanometers.

Behavioral Notes

Behavioral observations lasting from a few minutes to an hour were made on a total of 68 schools of spotted and spinner dolphins. The scientist in the

helicopter was primarily concerned with collecting aerial photographs, but after repeated observations of schools within a relatively short time frame, certain consistencies in porpoise and tuna behavior were noted.

Since the helicopter was frequently searching from 18-26 kilometers away from the vessel, schools were occasionally encountered in what appeared to be undisturbed feeding behavior. During this type of behavior, the schools were scattered in small subgroups that were often separated from each other by 180-270 meters. For spotted dolphins, these groups were typically of 3-9 animals while for spinner dolphins the groups were consistently larger (15-35 animals). In this configuration the animals frequently made steep dives and remained out of sight for extended periods. The tuna with these schools could not be directly observed at this time. Their location could be detected by the occasional slashing splashes made by these large fish swimming just below the surface and the concentration of birds in this area. These tuna signs were not directly associated with any of the porpoise sub-groups and mutualistic feeding behavior was not observed.

As the vessel approached, those schools that were in a configuration as described above slowly moved into a more concentrated body, became more polarized, and generally began to swim away from the ship. In mixed schools of spotted and spinner dolphins, the spinners consistently began to react to the ship by aggregating and moving away before the spotters did. The spotted dolphins generally made the transition to a more compact school as they moved in the same direction as the spinners. If the porpoise moved across the area in which tuna signs were visible, the tuna could be seen to begin swimming with the porpoise. If the porpoise school moved away from the area in which the tuna were located, the tuna signs would suddenly disappear from the surface and shortly afterwards the backs of fish could be seen with the porpoise.

While the porpoise school was swimming in this configuration, in which the main body of the school is almost a continuous mass with the average inter-animal distance estimated at about 6-8 meters and the animal proceeding in approximately the same direction, the majority of the tuna (80-90%) were generally visible at the head or on the flanks of the school. The tuna did not appear to be leading the school however, since changes in direction appeared to be initiated by the porpoise.

It was also noted that tuna swimming with porpoise are much more easily seen from the air when the school is swimming with the seas or down swell. It appears that tuna swim closer to the surface when they are headed with the seas.

DISCUSSION

The high correlation between estimates from aerial photographs and the estimates based on backdown counts indicate that aerial photographs can be an accurate source of school size data. The study produced no evidence to indicate that estimates from aerial photographs are lower than actual school size. For the one whole school that was successfully photographed and then captured and counted, the photographic estimate was 12.6% higher than the count. As was found after the aerial survey of 1979 (Holt and Powers, 1979), there was a high correlation between the estimates made by the scientist in the aircraft and those derived from the photographs. The excellent agreement between the photo estimates and the average of estimates made by the shipboard scientists and crew members on the *Gina Anne* cruise indicates that reliable school size data can be collected from ships if the personnel make a conscientious effort to follow estimation procedures. This supports the reliability of estimates collected from research ships, since on these ships 2-5 observers frequently combine their efforts to estimate the size of each school.

Average dolphin lengths taken from aerial photographs agree well with published averages for this species (Perrin et al., 1977; Perrin and Henderson, 1979). Aerial photography may provide a relatively large sample of length frequency data within a very short time frame. These data should be free from the age selectivity that may bias data collected from animals killed in sets. The accuracy of measurements from photographs can be easily improved by selecting a measuring instrument that is less subject to observer interpretation.

Both camera systems functioned well during the experiment. More schools were recorded successfully with the Hasselblad than the 5" camera because the Hasselblad was hand-held and could be pointed towards the schools if they were off the line of flight. This also meant that the full frame of the 2 1/4" transparencies could be kept free of the glitter of the sun on the water. Although the 5" camera had a footprint that was about 35% larger, it often lost

a large part of its effective path because it could not be trained away from the sun's glare. In future studies, fixed cameras should be placed in semi-rigid mounts that can be moved a few degrees in each direction off the aircraft's center line.

The quality of the transparencies produced by the high resolution KA51 camera were excellent but the footprint was too small to cover some of the larger dolphin schools. Probably the best camera for school size work is the KA62. This 5" camera has a 3" lense of slightly higher quality than the camera used in this experiment, and it has about the same footprint as our present 9" camera. The fast lenses of the 5" cameras make them excellent tools for marine photography. The ocean absorbs much more light than the land. Even the best 9" format mapping cameras have relatively slow lenses (maximum lense opening 5.6-6.3) because they are designed for terrestrial work. To use them at sea it is necessary to use fast films which have coarser grain. It is also often necessary to push-process the film which also increases the grain pattern. Since the lenses cannot be opened wide enough to accept adequate light, the shutter speed must be slowed to achieve proper exposure. The 5" cameras can use slower, fine grain films, faster shutter speeds, and still have enough light to allow the addition of filters if necessary.

From my observations of tuna with porpoise and conversations with experienced fishermen who have spent considerable time watching schools from helicopters, it appears that although tuna are generally at the head of a porpoise/tuna school, the tuna are clearly following the porpoise. The large percentage of the tuna are consistently found in areas of the porpoise school that have no sign of decaying splashes or wakes. It may be that tuna swim at the head of schools of porpoise or on their flanks to avoid swimming through the turbulence caused by the porpoise. It may also be the avoidance of surface turbulence that leads tuna to swim deeper when swimming into the seas.

- Allen, R., D. Bratten, J. Laake, J. Lambert, W. Perryman, and M. Scott. 1980. Cruise report of the M/V *Gina Anne* 11 October - 24 November 1979. Inter-American Tropical Tuna Commission, La Jolla, CA.
- Holt, R. and J. Powers. 1979. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys. Southwest Fisheries Center, La Jolla, CA.
- Perrin, W., D. Holts, and R. Miller. 1977. Growth and reproduction of the eastern spinner dolphin, a geographical form of Stenella longirostris in the eastern tropical Pacific. Fishery Bull.(75):725-750.
- Perrin, W. and J. Henderson. 1979. Growth and reproductive rates in two populations of spinner dolphins, Stenella longirostris, with defferent histories of exploitation. SWFC Admin. Rept. LJ-79-29.

TABLE 1 - School size estimates from aerial photographs and from counts at backdown.

[illegible]

TABLE 2 - School size estimates by crew members, scientists, and from aerial photographs.

School #	Ship		Helicopter		Aerial photographs
	Scientist	Crew member	Scientist	Crew member	
6	188		450	550	390
31	30		58		55
40		45	80		80
72	250	300	285	350	201
91	62	112	75		62
100			143		153
110	330	512	240	260	396
127	200	150	185	250	135
147	300	225	275	450	216
159	150	162	115	175	161
171	230	162	285	175	238

TABLE 3 - School size estimates for two schools photographed during the 1979 aerial survey.

School #	1979 Estimates				Present Study			
	n	Range	sd	$\bar{x}$	n	Range	sd	$\bar{x}$
4	3	130-145	8.14	139.3	5	121-152	11.71	139.8
34	3	265-304	21.46	289.7	5	256-352	36.63	298.6

TABLE 4 - Length frequency of dolphins measured from photographs.

School 72

Lengths mm	No.
10.6-11.0	2
14.6-15.0	1
16.6-17.0	5
18.6-19.0	1
21.6-22.0	1

School 127

Lengths mm	Measure- ments	Lengths mm	Measure- ments	Lengths mm	Measure- ments	Lengths mm	Measure- ments
8.1-8.5	2	9.6-10.0	1	11.1-11.5	26	12.6-13.0	18
8.6-9.0	1	10.1-10.5	2	11.6-12.0	25	13.1-13.5	5
9.1-9.5	3	10.6-11.0	16	12.1-12.5	21	13.6-14.0	1

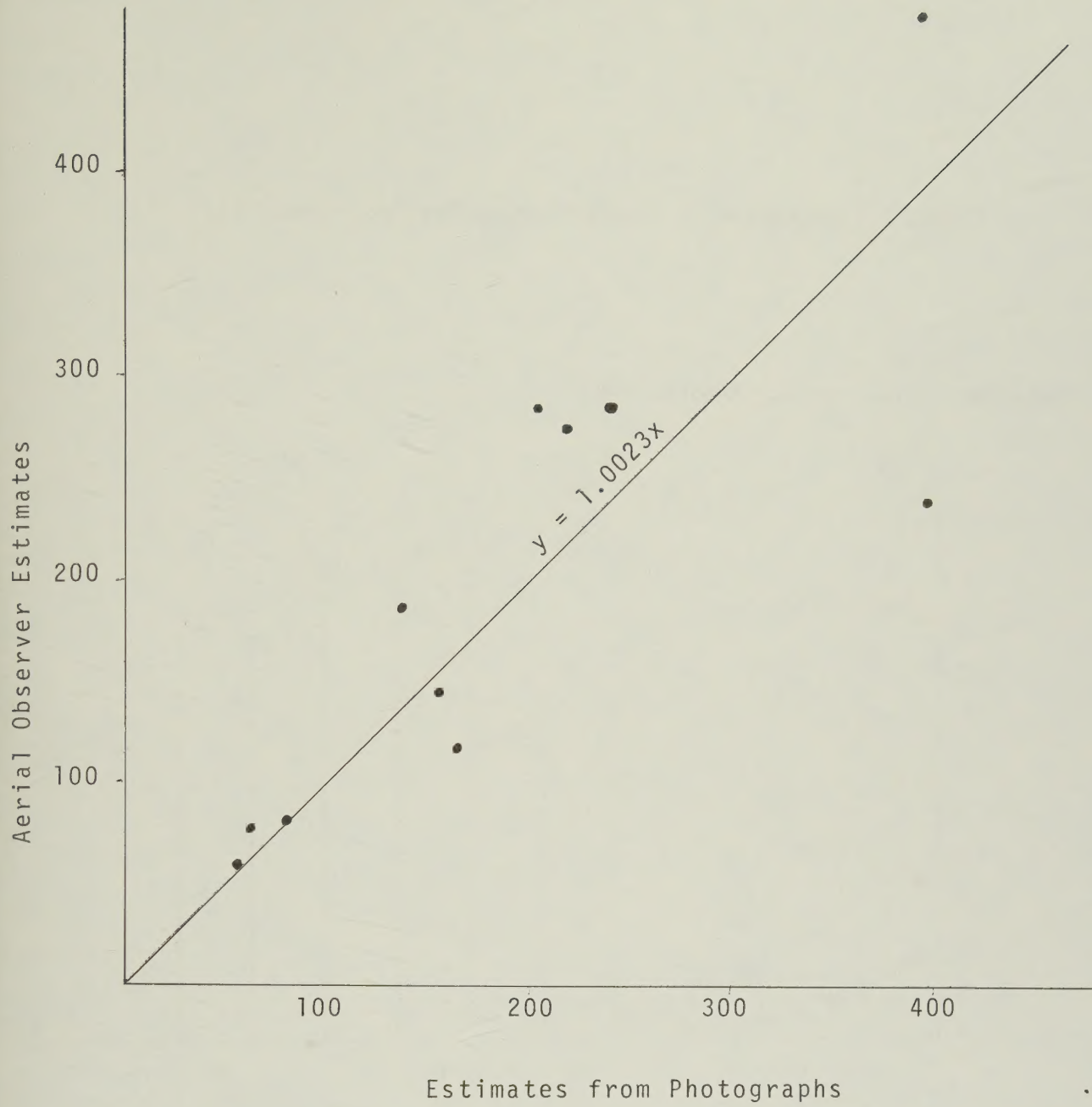


FIGURE 1 - Linear regression through the origin for photographic and aerial observer school size estimates.

FIGURE 2 - Histogram of length frequencies from school 127.

